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The retrospective issue with estimates of maturity for 2J3KL cod (*Gadus morhua*)

Le problème rétrospectif avec les estimations d'échéance pour 2J3KL morue (*Gadus morhua*)

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ABSTRACT

Estimates of spawning stock biomass (SSB) for many populations are calculated by applying female maturity at age, estimated on a cohort basis, to total biomass. Over the life of a cohort, data are added for an additional age each year. This means that until the age at which the maturation process is complete, estimates are based on incomplete data for a cohort. This results in potential changes in estimates of proportion mature at age from one assessment to the next. During the 2007 assessment of northern cod, concern was raised that this might introduce a retrospective pattern in SSB. The recommendation to carry out further examination of the maturity data and model, and to carry out comparative analyses for the next assessment was addressed. Models of proportion mature at age within a cohort are refit using data from progressively fewer years and the resulting estimates compared. SSB calculated using these estimates of proportion mature at age produced with differing amounts of data and a constant matrix of population numbers at age were compared to examine the impact of the method on both retrospective and projected estimates of SSB. As expected there are some differences between estimates of proportion mature at age for Div. 2J3KL cod, depending on the age range over which data were available. The magnitude of these differences varied from cohort to cohort. The impact of these differences in estimates of proportion mature at age on estimates of SSB was relatively minor. The impact on projections was somewhat greater than the impact in retrospective analyses. In neither case were there differences in trend caused by the different maturity estimates (i.e. no cases where one set of maturity estimates resulted in an increase in SSB while another resulted in a decrease). The impact of the current method of estimating maturity at age for Div. 2J3KL cod appears to be minimal.

RÉSUMÉ

Pour établir les estimations de la biomasse du stock reproducteur (BSR) de nombreuses populations, on applique la maturité des femelles à l'âge, estimée par cohorte, à la biomasse totale. Tout au long de la vie de la cohorte, on ajoute chaque année des données pour un âge additionnel. Ainsi, jusqu'à l'âge de l'achèvement du processus de maturation, les estimations sont fondées sur des données incomplètes pour la cohorte. Les estimations de la proportion d'individus matures à l'âge peuvent donc changer d'une évaluation à l'autre. Pendant l'évaluation de 2007 de la morue du Nord, on s'est inquiété du fait cela puisse introduire un profil rétrospectif dans la BSR. La recommandation d'effectuer un examen plus poussé des données et du modèle sur la maturité ainsi que des analyses comparatives pour la prochaine évaluation a été prise en considération. On a refait les modèles de la proportion d'individus matures à l'âge dans une cohorte grâce à des données recueillies pendant une séquence de quelques années et on a comparé les estimations obtenues. Pour examiner l'impact de la méthode sur les estimations rétrospectives et prévues de la BSR, on a comparé la BSR calculée à l'aide des estimations de la proportion d'individus matures à l'âge produites avec différentes quantités de données et une matrice constante de l'effectif à l'âge. Tel que prévu, il y avait certaines différences entre les estimations de la proportion d'individus matures à l'âge pour la morue de la division 2J3KL, selon la fourchette d'âge pour laquelle on disposait de données, et leur importance variait d'une cohorte à l'autre. Ces différences dans les estimations de la proportion d'individus matures à l'âge ont eu un impact relativement minime sur les estimations de la BSR. L'impact sur les prévisions était quelque peu plus important que celui dans les analyses rétrospectives. Dans ni l'un ni l'autre cas, il n'y avait pas de différences dans la tendance causée par les différentes estimations de la maturité (c.-à-d. qu'il n'est pas arrivé qu'un ensemble d'estimations de la maturité ait entraîné une hausse de la BSR et qu'un autre ait entraîné une baisse). L'impact de la méthode d'estimation actuelle de la maturité à l'âge pour la morue de la division 2J3KL semble être minime.

INTRODUCTION

Estimates of spawning stock biomass (SSB) for many populations are calculated by applying female maturity at age estimated on a cohort basis to total biomass. This method of estimating maturities is more reflective of the biological reality of maturation than the previous method of estimating maturities annually (Morgan 2000). Over the life of a cohort, data are added for an additional age each year. This means that until the age at which the maturation process is complete, estimates are based on incomplete data for a cohort. Currently, the average estimate from the most recent three cohorts is used for age/cohort combinations for which there is not sufficient data to produce a significant model fit. Once data are sufficient for model fit to be significant then the estimates from the model fit are used and the estimates updated in each subsequent year until the point at which all fish in the cohort are mature (Lilly et al. 2006). This method results in potential changes in estimates of proportion mature at age from one assessment to the next as more data are accumulated for incomplete cohorts. During the 2007 assessment of northern cod concern was raised that this might introduce a retrospective pattern in SSB (DFO 2007).

From the proceedings of the 2007 northern cod assessment:

'There was discussion on the way maturity data are treated and the modelling details. It was highlighted that the problem is that one is trying to fit a shape when the data are only available for half of that shape. The only way of knowing for sure is 'after the fact'. It was suggested that this could be examined in more detail, but that rapid changes could also be real. It was also agreed to use the information as presented for this assessment.

It was **recommended** to carry out further examination of the maturity data and model, and to carry out comparative analyses for the next assessment.'

This paper addresses this recommendation for 2J3KL cod. Models of proportion mature at age within a cohort are refit using data from progressively fewer years and the resulting estimates compared. SSB calculated using these estimates of proportion mature at age produced with differing amounts of data and a constant matrix of population numbers at age are compared to examine the impact of the method on both retrospective and projected estimates of SSB.

MATERIALS AND METHODS

Maturities were modeled by cohort as a function of age using generalized linear models with a logit link function and binomial error (McCullagh and Nelder 1983). Models were fit to survey data for each cohort starting with data from the fall of 2006. Models were successively refit using 1 year less data each time. Models were refit 11 times going back to the 1995 survey.

After each refit of the model, results were examined to determine if there was any consistency in the number of ages required before there was a significant model fit (both the slope and intercept significant at the 0.05 level). Results were also examined to determine the age after which there was little or no change in parameter estimates with the addition of further data.

Cohorts which had data extending from age one up to at least the age at which there was no further change in parameter estimates were chosen to compare estimates with differing amounts of data. Estimates using the average of the previous 3 cohorts, estimates from the first year in which there was a significant model fit, and estimates once the cohort reached the age at which there was no further change, were compared. In addition, estimates using data to age 4 (first significant model fit), age 5, age 6 and age 7 were compared. Estimated proportion mature at age for each of these cases was plotted. The difference between the estimates was examined by calculating the sum of the absolute value of the differences in proportion mature at age between each case (e.g. proportion mature at age a and cohort y from averaging minus proportion mature at the same age for the same cohort from the first significant model fit).

The effect of fitting the models with different amounts of data on estimates of SSB was examined. In all cases the same matrices of numbers at age and weights at age were used so that the only thing that varied was the matrix of proportion mature at age. A series of matrices of estimated proportion mature at age was constructed as they would have been in each assessment year from 1996 to 2007. In each year, cohorts/ages for which there was no significant model fit were filled with the average for that age of the last three cohorts and the rest were estimated from the generalized linear models, with data up to the latest survey used in the assessment. SSB for each year from 1995 up to and including the assessment year (e.g. 1995-2007 or 1995-2006) was calculated as number at age * weight at age * proportion mature at age.

The effect on 3 year 'projections' of SSB of including different amounts of data in the estimates of maturity was also examined. Numbers at age were not actually projected but rather the same number at age matrix was used in each case and the maturities were treated as if they were being used in a projection. That is, for cohorts with a significant model fit estimates from the model fits were used. For those without a significant model fit, the average of the last 3 cohorts at that age was used.

RESULTS

For all cohorts examined, a significant model fit was achieved when there were data up to age 4. There was some variation in the age beyond which the addition of data did not change parameter estimates, but for all cohorts examined the ogive was 'fixed' by age 7 (Fig. 1).

Over the 1995-2006 time period, the 1992-98 cohorts had data ranging from less than age 4 (no significant fit) to age 7 or greater (ogive fixed). These cohorts were chosen to examine the effect of adding more data on the estimated proportion mature at age. For each cohort the ogive produced from averaging the previous 3 cohorts with a significant fit, the ogive produced with the first significant model fit for the ogive (at age 4) and the cohort produced at age 7 were plotted (Fig. 2). In addition, the absolute value of the difference in the estimates from the different methods was calculated for each age from 1 to 10 and the s' m of the differences calculated for comparison. In most cases there was little difference between the estimates, but generally the fitted ogives tended to be more similar to each other than they were to the ogive produced from averaging the estimates for the 3 previous cohorts. However, differences were small. This can be seen by comparing the sum of the absolute value of the difference between the estimates. This was 2.1 for the fit at age 4 vs the fit at age 7, while the fit at age 4 vs averaging gave a sum of the absolute differences of 2.5 and the fit at age 7 compared to averaging gave a sum of 2.4. For most

cohorts there was little difference in estimates from fitted ogives using data up to age 4, 5, 6 or 7. The 1995 and 1996 cohorts showed the most difference in the estimates (Fig. 3).

Although some of the older ages were missing or had very low sample size in recent years, the number of fish sampled at the ages where fish were maturing (mainly ages 4-6) were reasonable for most cohorts (Table 1).

Estimates of SSB were produced from 2007 back to 1996, each year using one less year in the number at age and weight at age matrices. The maturities at age that were used were as they would have been in that assessment year, i.e. using data only up to and including from the survey of the previous autumn. There was little impact of using less data in the estimation of a cohort on the estimate of SSB (Fig. 4).

Three year 'projections' were compared for each assessment year from 1996 to 2007. In this process, numbers at age and weights at age were the same matrices as used in the retrospective analyses rather than projections of numbers and weights. Only the maturities were treated in the same manner as they would be in a projection. This allowed the impact of projection of maturities alone to be examined. In most cases the difference in estimated SSB was less than 5%, although the estimate for 2007 varied by 15% (Fig. 5). The difference is somewhat greater than for the retrospective analyses (Fig. 4).

DISCUSSION

As expected there are some differences between estimates of proportion mature at age for Div. 2J3KL cod, depending on the age range over which data are available. The magnitude of these differences varies from cohort to cohort.

The impact of these differences in estimates of proportion mature at age on estimates of SSB is relatively minor. The difference on projections was somewhat greater than the difference in retrospective analyses. In neither case were there differences in trend caused by the different maturity estimates (i.e. no cases where one set of maturity estimates resulted in an increase in SSB while another resulted in a decrease).

The impact of the current method of estimating maturity at age for Div. 2J3KL cod appears to be minimal.

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Table 1. Sample size at age for cohorts from 1978 to 2002. A dot indicates that the age was not sampled. NA indicates that the cohort has not yet reached that age.

cohort	Age1	Age2	Age3	age4	Age5	Age6	Age7	age8	Age9	Age10
1978	.	.	.	187	191	147	162	155	110	118
1979	.	.	112	166	115	245	171	101	107	100
1980	.	16	204	173	211	156	117	126	117	98
1981	2	51	168	192	192	127	149	162	173	134
1982	1	76	168	135	135	162	173	166	200	74
1983	3	102	85	95	89	100	107	101	60	6
1984	.	5	103	128	107	96	110	79	9	.
1985	.	26	92	206	152	117	139	49	2	.
1986	.	22	190	191	187	183	107	14	2	.
1987	.	46	245	244	206	190	64	6	.	3
1988	.	49	111	97	99	77	9	3	4	1
1989	2	38	138	157	129	25	15	11	5	1
1990	.	8	75	111	43	31	18	2	2	2
1991	.	1	91	38	77	38	.	5	2	1
1992	.	.	14	160	101	21	11	.	2	1
1993	.	2	148	166	44	38	10	2	1	.
1994	.	125	261	150	97	26	6	3	.	.
1995	2	113	106	99	40	23	11	.	.	.
1996	.	8	53	139	86	51	7	.	1	.
1997	2	43	182	109	86	31	4	2	1	3
1998	2	85	122	182	107	14	11	2	5	NA
1999	8	87	150	128	55	24	7	4	NA	NA
2000	2	79	173	101	57	33	23	NA	NA	NA
2001	1	83	89	84	96	76	NA	NA	NA	NA
2002	3	168	209	169	124	NA	NA	NA	NA	NA

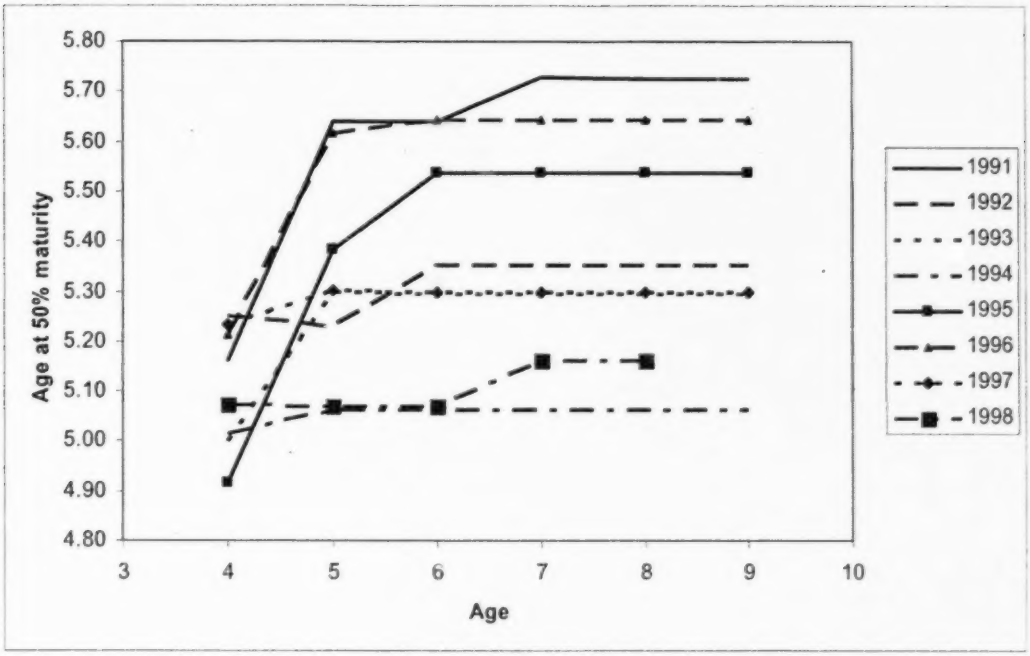

Figure 1. Estimated age at 50% maturity versus the age at which the estimate was made for cohorts 1991-98.

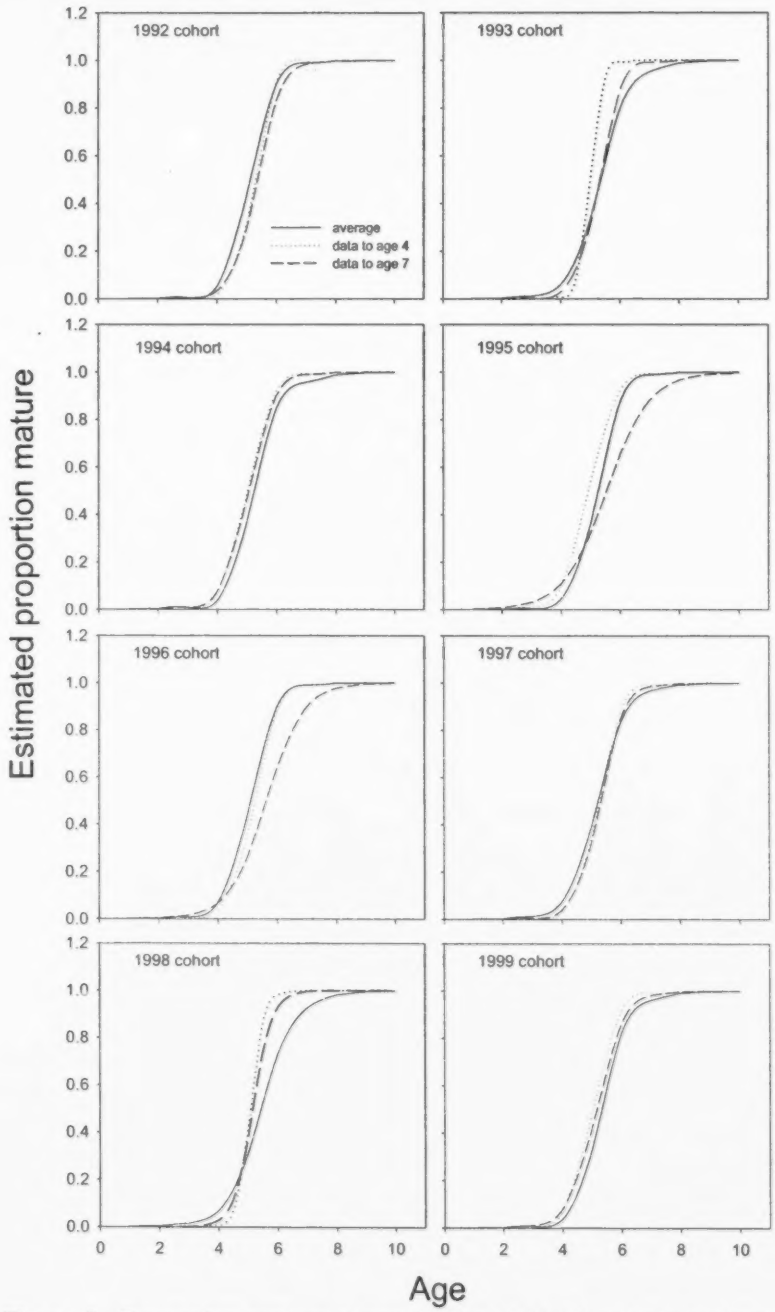

Figure 2. Proportion mature at age for the 1992-99 cohorts estimated as the average of the 3 previous cohorts (solid line), estimated from a generalized linear model using data to age 4 (dotted line) and from a generalized linear model using data to age 7 (dashed line).

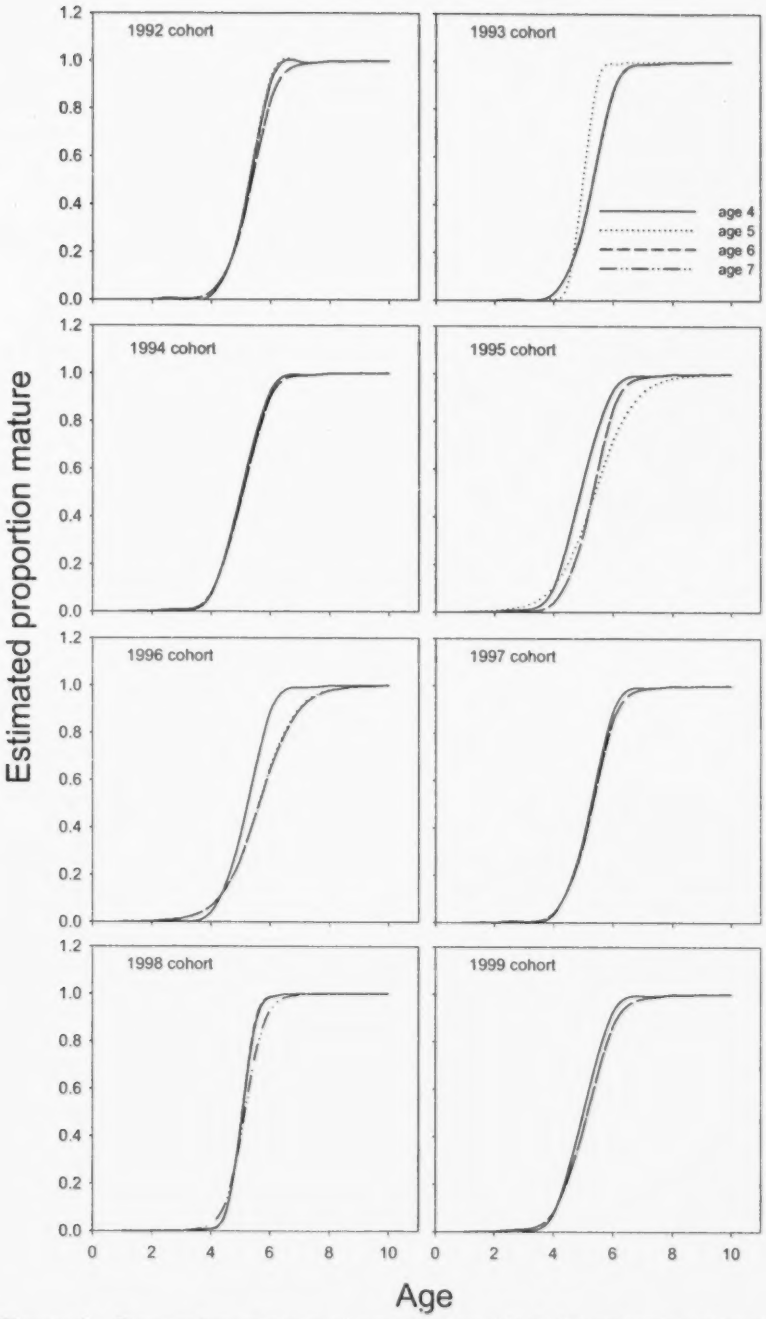

Figure 3. Proportion mature at age for the 1992-99 cohorts estimated from a generalized linear model using data to age 4, age 5, age 6 or age 7.

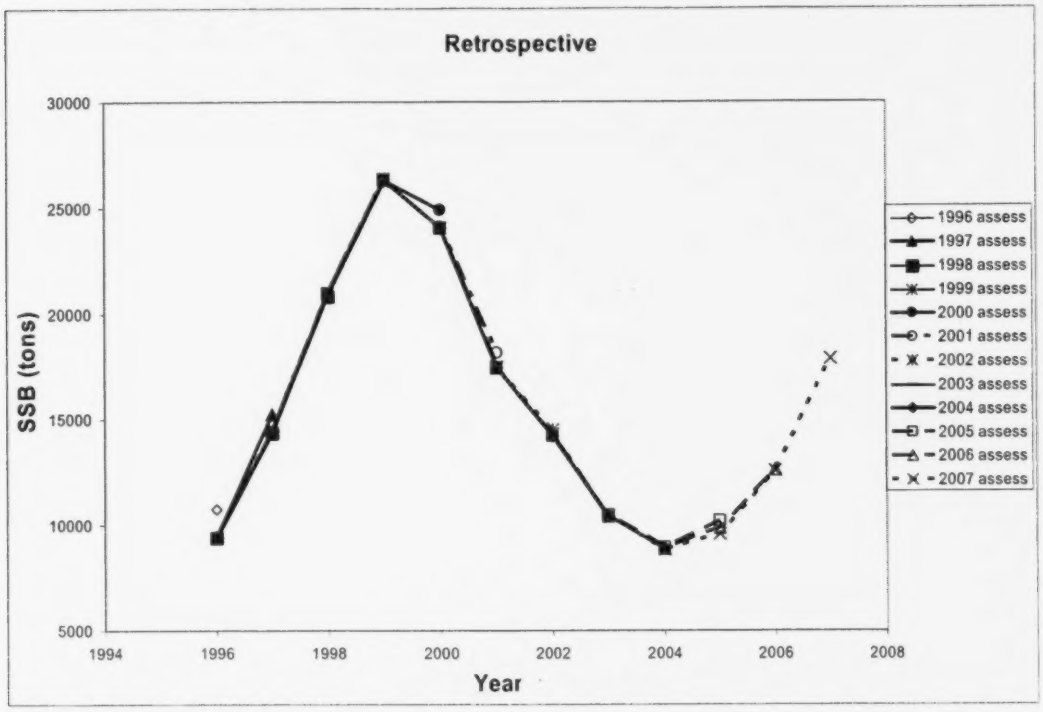

Figure 4. Estimates of SSB derived using the same matrix of numbers and weights at age and varying estimates of maturity at age. The maturities are estimated using one year less data from 2005 to 1995. The estimates of SSB reflect the assessment year. That is the line labeled '2006 assessment' uses numbers and weights up to 2006 and maturities as they would have been in the 2006 assessment.

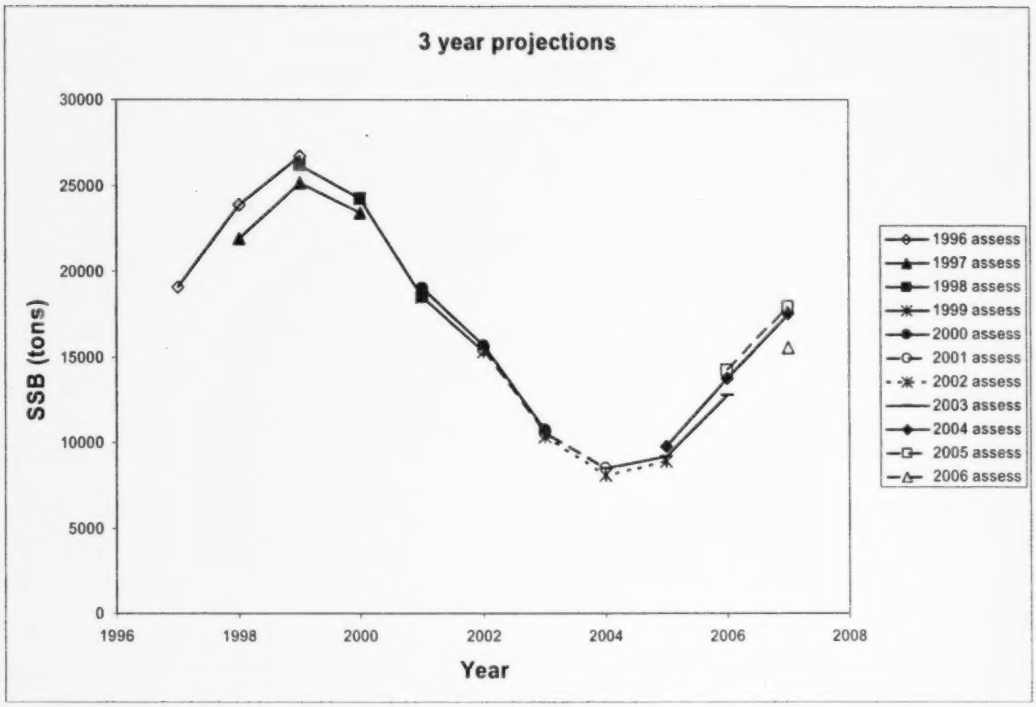

Figure 5. Estimates of SSB derived using the same matrix of numbers and weights at age and varying estimates of maturity at age. The maturities are estimated using one year less data from 2005 to 1995. The estimates of SSB reflect 3 year projections from the assessment year. Only the maturities are projected.